Digital Twin. Experimenting drawings (di-SEGNI) between science and technology in teaching

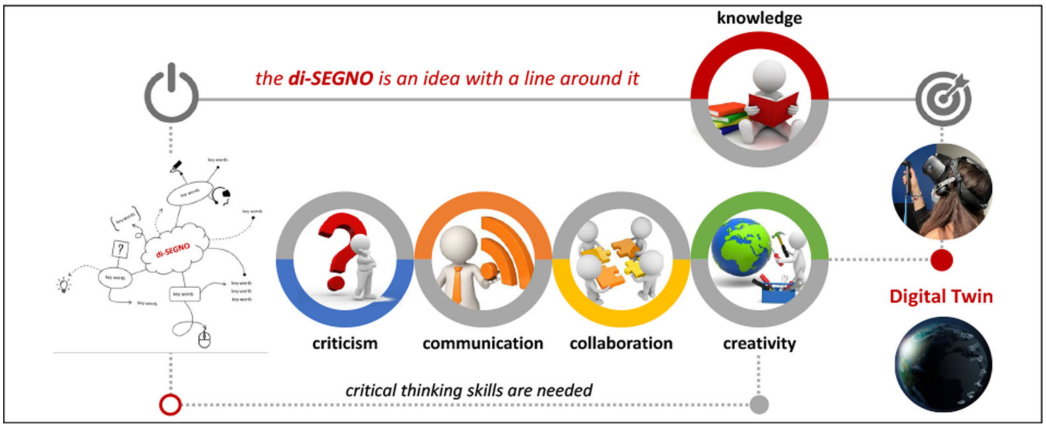
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Abstract

The teaching of Drawing must constantly face new challenges due to two essential elements that change over time and are closely interconnected: the technological innovation of the tools and the multidisciplinary enrichment of the contents. In this context, the Digital Twin requires that the Drawing be re-thought to define a perfect graphic and alphanumeric synthesis of static and dynamic contents, in order to guarantee a correct use of information within a decision-making process based on data and their reliability. The close correlation between research and teaching activities on multi-representation systems in terms of Digital Twin, allows us to open dialogues with multiple disciplines "other" than Drawing, as presented in this contribution, where the interoperable management of data (between people and between tools) is placed at the center of the knowledge and planning activities of a territory, a city, or a building in terms of resilience and energy saving. For this to happen, a review of the curricula is necessary to strengthen the role of the Drawing, as *an idea with a line around it*, that is, as a language able of stimulating and training students to correlate and synthesize the data they receive from different teachings using appropriate tools and methods.

Keywords
Digital Twin, BIM, interdisciplinarity, Virtual and Augmented Reality

Topic
Visualising



Role of the di-SEGNO, as an idea with a line around it. (Author's elaboration).

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Introduction

Many types of research show that the didactics of Drawing must constantly face new challenges due to two essential elements that change over time and are closely interconnected: the technological innovation of tools and the multidisciplinary enrichment of contents. In this context, the Digital Twin, allowing a virtual replica of places, infrastructures, objects, people, processes and systems, is a significant element of experimentation for a correct static and dynamic representation of the building, the city and the territory between research and teaching. By stimulating the convergence of different interdisciplinary ways of looking at things, the Digital Twin allows a great innovation concerning physical models or two- and three-dimensional drawings that have been consolidated over time. It becomes an opportunity for the digital representation of cognitive and decision-making processes concerning a built environment with increasingly complex and heterogeneous relationships (Smart Cities). Suppose the goal of the Digital Twin is to achieve synchronisation of the real world with a virtual platform [Deng et al. 2021]. In that case, it cannot disregard the integration of data (Big Data) typical of different disciplinary fields: (i) historical and bibliographic research for knowledge of phenomena and understanding of transformations; (ii) GIS (Geographic Information Modeling) for study at the urban and territorial scale; (iii) ScanToBIM (from point cloud to Building Information Model) for study at the building scale; (iv) IoT (Internet of Think) for real-time information gathering; (v) VAR (Virtual and Augmented Reality) for data visualisation. To guarantee the exact construction of a Digital Twin, the di-SEGNI must derive from a careful reflection on a perfect graphic and alphanumeric synthesis of the contents. The aim is to guarantee the correct fruition of the information within a decision-making process based on data and its reliability (LoR - Level of Reliability) [Maiezza, 2019]. BIM (Building Information Modeling) provides a working methodology based on data that allows a standardised semantic representation of components and systems. While the Digital Twin conveys a more holistic, process-oriented characterisation of the complexity of the elements involved, exploiting the synchronicity of bidirectional data flows between the virtual and the real world [Boje et al., 2020]. All this requires a sharing of standards yet to be consolidated.
This paper presents the use of Digital Twins in education to study: (i) the resilience of the built environment at the urban scale; (ii) the transformation of the built environment into a "Green Building". An interdisciplinary approach involving four different disciplinary fields within single teaching was used to implement the Digital Twins. The results obtained by the students describe with a critical synthesis the complexity and heterogeneity of the data used and become a tool of knowledge for the subsequent design phase, addressed in the context of other courses.

Methodology

The close correlation between research and teaching activities on multi-representation systems in Digital Twin has opened up dialogues with multiple disciplines 'other' than Drawing (fig. 01). This, in 2018-19, led to an overall revision of the curriculum of the Master's degree (LM) in Construction Engineering and allowed di-SEGNO to outline the features of the interdisciplinary dialogue based on the understanding with which representation must be conceived, realised and enjoyed today. As demonstrated by the results obtained in the twin courses "Knowledge of the built heritage in the era of climate change" and "Knowledge of the built heritage in the era of climate change", interesting technical and operational synergies have been created between the various disciplinary sectors involved.
The first, Resilience of the Built Environment, is based on creating a digital model at the urban scale (the Digital Twin of the Resilient City). The second is the Green Building, in which a digital model is developed at the building scale (the Digital Twin of the Green Building).
The objective is to set the methodological foundations of the entire course of studies, providing innovative tools and methods for the integration and critical interpretation of heterogeneous data functional to the design that characterizes the two addresses.

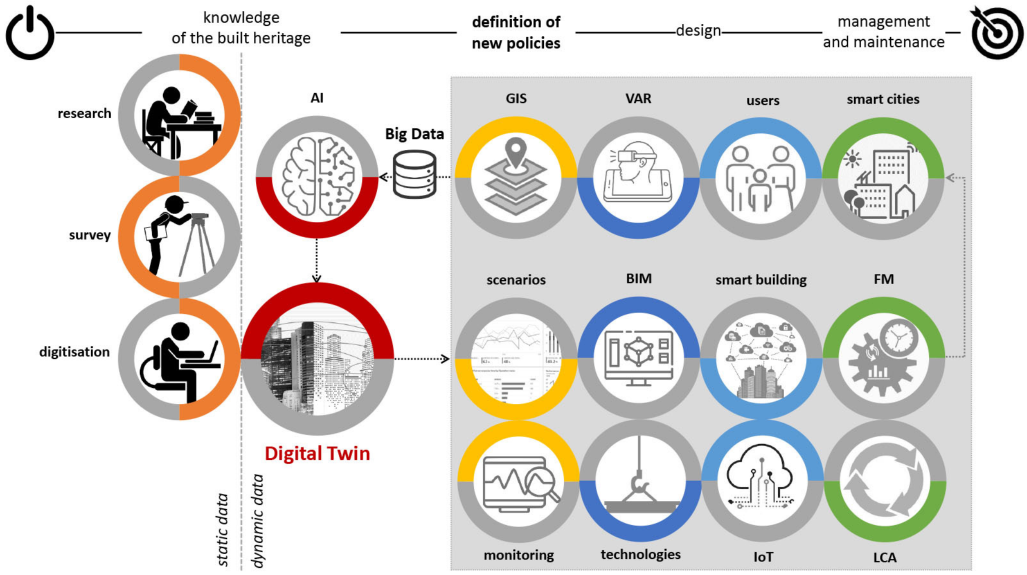


Fig. 01. Contents of Drawing as a language for multi-representation systems. (Author's drawing).

As the literature shows, since the mid-20th century, the demands of multi-disciplinary aspects in education have made it possible to develop paradigms for moving from mono-disciplinary to inter-disciplinary teaching [You 2017].
Thus, interdisciplinary teaching has become increasingly important over time, allowing students to harmonise the learning of several disciplines to find new ways of thinking about problems and how to solve them, developing crucial critical thinking skills.
The elements underlying this transformation can be summarised as follows: (i) contextualisation, to correctly place the information in the historical, cultural and technological context in which one is working; (ii) conceptualisation, to scientifically exploit different standards for the integration of information coming from heterogeneous sources; (iii) problem-based investigation, to identify the essential elements on which to focus and from which to start to propose new design solutions for transformation and/or conservation from the territorial scale to the building scale [Nikitina, 2007].
In this context, "Conoscenza del patrimonio costruito …" and "Knowledge of the built heritage ..." (18 CFU) have been designed as compulsory courses in the first semester of the first year and include four contributions from lecturers from four departments (18 CFU), have been conceived as mandatory courses in the first semester of the first year and include four contributions from lecturers from four departments: 8 CFU *Drawing* (ICAR-17, Department of Structural, Building and Geotechnical Engineering); 2 CFU *Environmental Physics* (ING-IND/11, Department of Energy); 4 CFU *Geomatics* (ICAR/06, Department of Environmental, Land and Infrastructure Engineering); 4 CFU *Information Processing Systems* (ING-INF/05, Department of Computer Science and Automation).
The lessons are organised with a constant presence of Drawing and an alternation of the other disciplines, according to a logical sequence dictated by the contents of the exercise (fig. 02).
This has guaranteed the critical elaboration of all the static and dynamic information that, in their heterogeneity and complexity, must compose the Digital Twin set from the beginning as the final objective. The case study is chosen each year with the agreement of all the teachers involved in the first year of the LM of the two courses because it is the subject of practice for all the courses.
This optimises the students' commitment and a more in-depth elaboration of the urban context under investigation, ranging from knowledge of the built heritage to integral design, with a particular focus on the single mono-disciplinary subjects that characterise the two courses.
The didactic methodology adopted was based on the interoperability between multiple domains [Ugliotti et al., 2021].

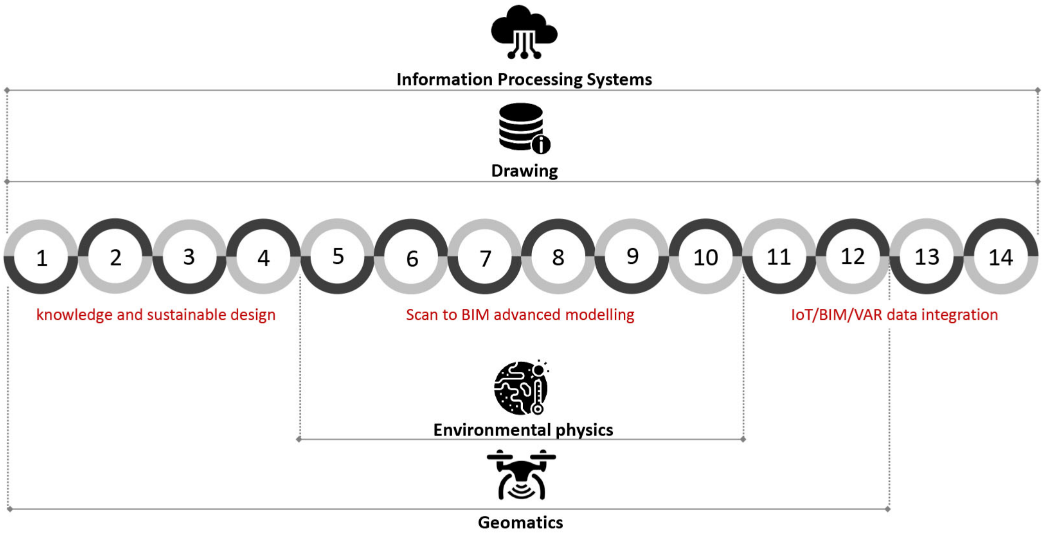


Fig. 02. Outline of teaching organisation over the 14 weeks of the semester. (Author's drawing).

This has allowed us to identify, step by step, the contents of the Digital Twin so that it can be used for the design in terms of Smart City or Green Building of the investigated context to improve the quality of life of the users in terms of resilience of the built heritage and energy saving. The initial assumption was that the Digital Twin should not be an iconographic representation of the real world incorporating alphanumeric information derived from the IoT but instead is a meaningful graphical and alphanumeric abstraction of real physical assets and data. This can only be achieved by assigning the di-SEGNO the natural role of a language capable of describing an object by simplifying it to its essence.
As can be seen, from (fig. 03), the data processed concerning information derived from (i) the historical-bibliographical research; (ii) the endotypes developed on-site; (iii) from the laser scanner and drone survey (point cloud); (iv) from the parametric modelling in BIM, characterised by different LoG (Level of Geometry), LoI (Level of Information) and LoR (Level of Reliability); (v) object-oriented modelling of the most complex elements; (vi) energy simulations about the different thermo-energetic characterisations of the envelope components; (vii) structural simulations to seismic verifications; (viii) object-oriented programming for the simulation of IoT data. To achieve the desired objective, various tools were used in the different areas.
This didactic model is comparable to interdisciplinary teaching in the curricula of other universities. However, it is not so usual to have computer science as a compulsory discipline in an LM in Construction Engineering. However, there is no evidence of courses of study in which all the lecturers involved in the first-year work together, sharing the same case study, to guarantee students a high level of in-depth knowledge of the final result. This choice was shared with the stakeholders involved from the early stages of designing the new study pathway. Potential problems can be found in the management of groups of students who, for different reasons, do not have to follow all the subjects.

Results

The findings of influential design studies on the use of the Digital Twin demonstrate how the Digital Twin has the potential to transform the methodology with which we approach the design and management of the built environment. The report [ARUP, 2019] describes nicely how the experience of Smart Cities has shown that city administrations have struggled to manage technology and data strategically. This has led to problems with knowledge of state of the art, the ability to manage heterogeneous data, a collaboration between multi-

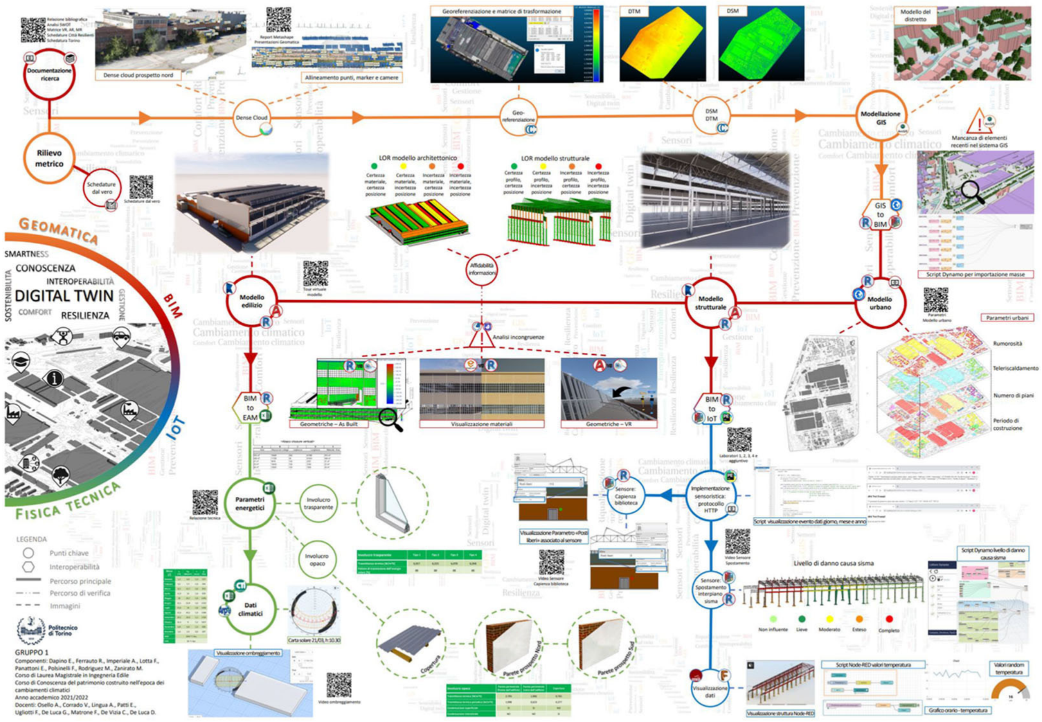


Fig. 03. Example of data processing (Students: Dapino E., Ferrauto R., Imperiale A., Lotta F., Panattoni E., Poslinelli F., Rodriguez M., Zanirato M.)

ple parties (public and private), and optimisation between research and development for innovation in the urban environment. Probably, the same issues will apply to the adoption of the City Digital Twin. With the proposed didactic model, the theme of interoperable data management (between people and between tools) is placed at the centre of the knowledge and design activities of a territory, a city or a building, and finds in the Digital Twin the right way for the di-SEGNO of information, as a multi-representation system to (i) understand the historical evolution of the urban area investigated; (ii) observe the state of conservation of the different building components; (iii) simulate the energy and structural performance of the artefacts; (iv) map the resilience of territory about different factors; (v) experiment with management tools typical of ICT (Information and Communication Technology) to manage static and dynamic data; (vi) visualise information in virtual and augmented reality; (vii) elaborate new design solutions; (viii) share information. The results were compared with the literature on research and teaching topics and were the subject of an exhibition attended by the stakeholders involved in revising the curricula. The (fig. 04) summarises the results of the two years of teaching activities comparatively. As can be seen from the tables, the representation of the Digital Twin is always symbolic and placed in a strategic position concerning the different sources of the data investigated and shared. The most interesting result emerges in (fig. 05), where students chose the image of an underground map to represent the interdisciplinary contributions of the individual lessons to identify the key elements that led to the definition of the Digital Twin placed in the centre.
It can be observed (fig. 06) that the Digital Twin's di-SEGNO corresponds to a three-dimensional model with a low level of detail (LOD 100) that allows access to the different Data Bases where it is possible to store: (i) 'red line', the information related to the surveying and survey activities, linked to BIM modelling and sensor management with BMS (Building Management System); (ii) 'green line', the GIS map themes for reading the information related to Smart Buildings and their Network; (iii) 'blue line', the information needed for a correct Governance based on the concept of Resilience; (iv) 'yellow line', the information needed for the definition of new Sustainability Policies, in response to possible Shocks, using Interoperability, Visual Programming Language and Artificial Intelligence. With this didactic approach



Fig. 04. Comparative analysis of students' tables. (Author's elaboration).

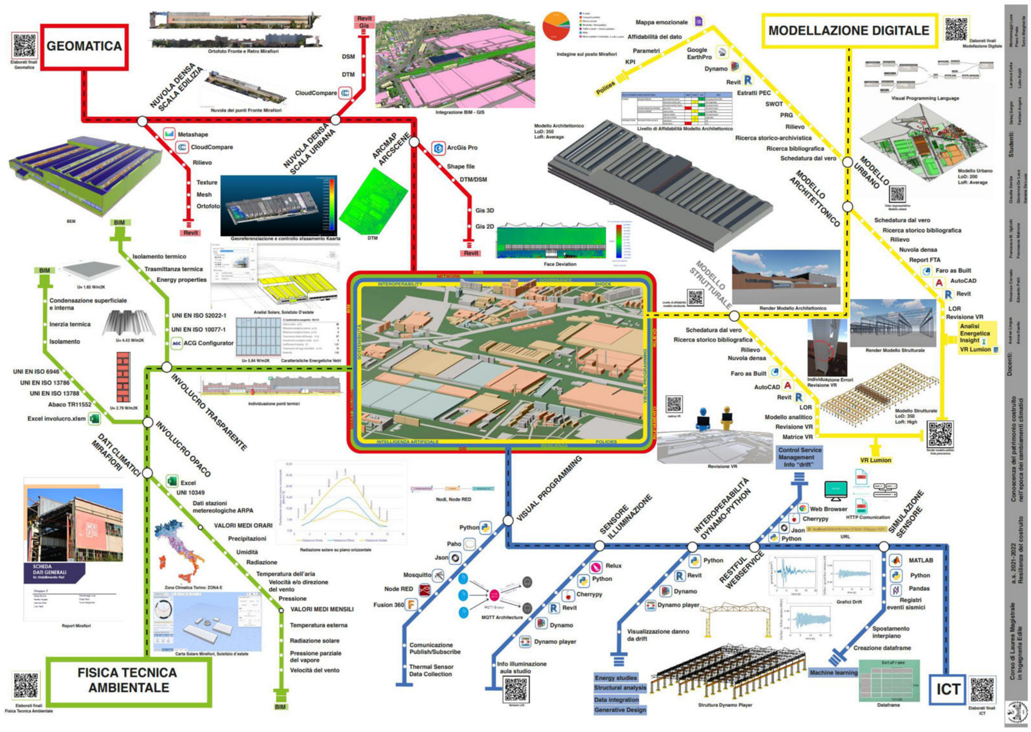


Fig. 05. Example of data processing (Students: Turco M., Fanfani A., Montemaggi L., Prete P., Luku K., Laronca C., Dakaj S.)

based on interdisciplinarity and the graphic synthesis typical of di-SEGNO, the students have demonstrated their ability to master what technology offers them. Above all, they know how to use science as a methodological approach to cognitive problems, starting with a careful analysis using specific KPIs (Key Performance Indicators) (fig. 07). The implications of this work are considerable, as it will enable the new generations of professionals to face the challenge of digitisation with a method and content-based scientific rigour, always using the most appropriate tools.

Conclusions

The Digital Twin represents one of the main challenges that the didactics of Drawing must face to contribute to the Destination Earth project, solicited by the European Community to create a high-precision digital model of the Earth to model, monitor and simulate natural phenomena and related human activities.

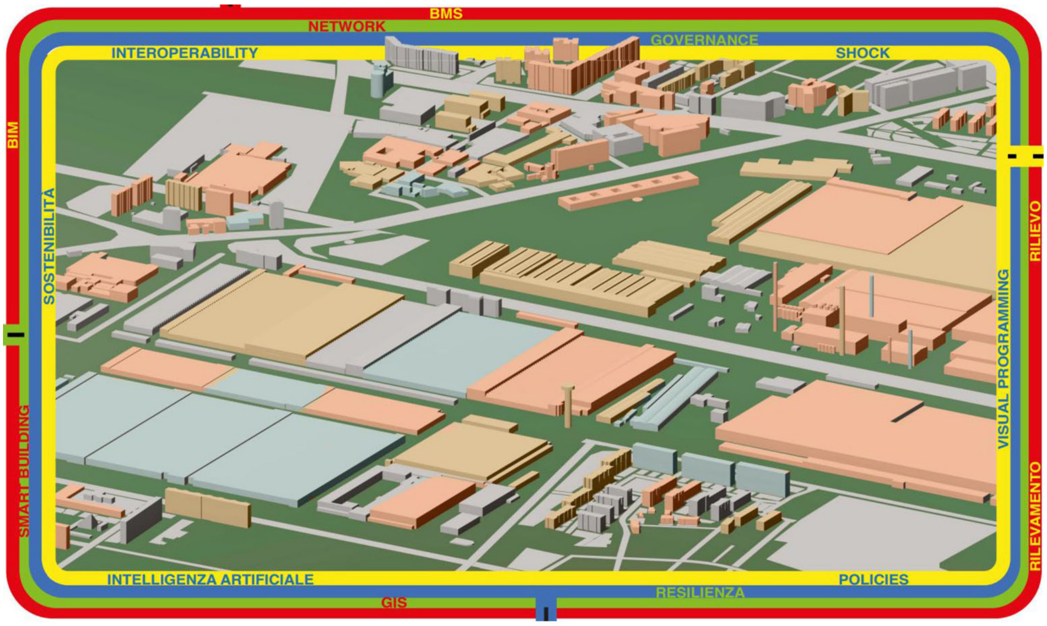


Fig. 06. Detail of previous figure (Students: Turco M., Fanfani A., Montemaggi L., Prete P., Luku K., Laronca C., Dakaj S.)

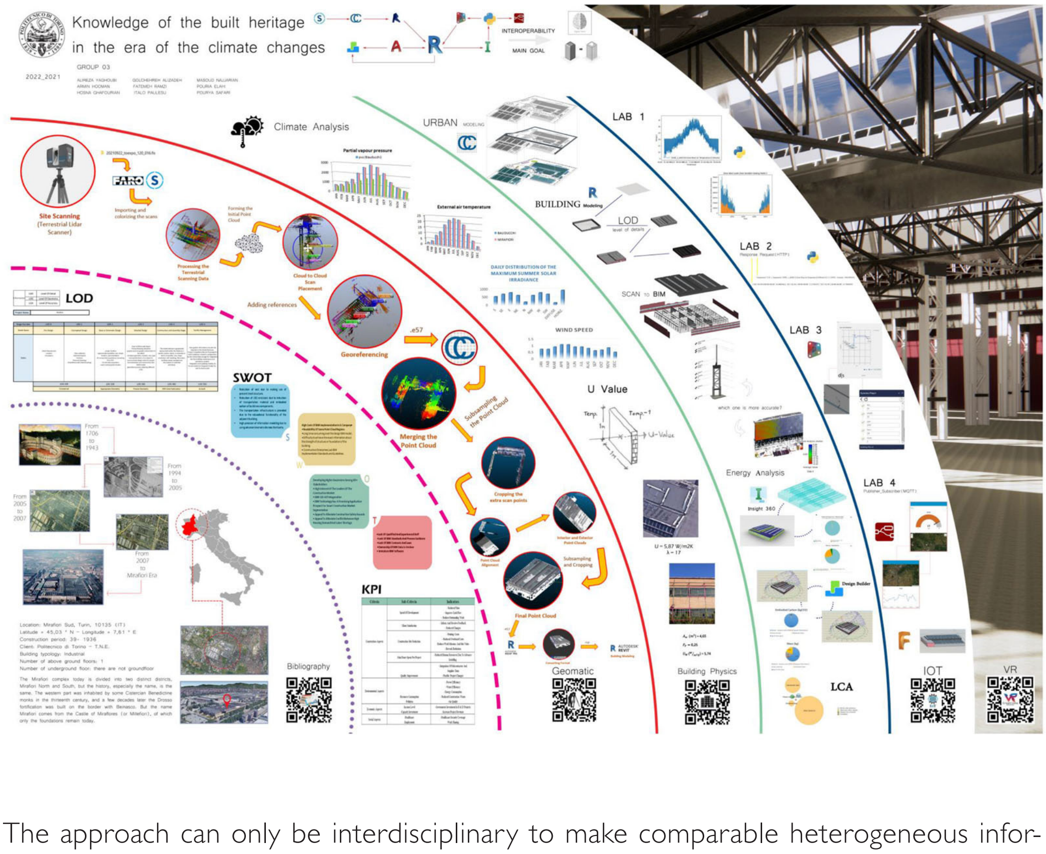


Fig. 07. Example of data processing (Students: Ghafourian H., Alizadeh F., Najjarian M., Hooman A., Alahi P., Safari P., Yaghoubi A., Ramzi F., Paulesu I.)

The approach can only be interdisciplinary to make comparable heterogeneous information databases enriched over time. This should require a revision of the curricula to strengthen the role of di-SEGNO, as an idea with a line around it, i.e. as a language capable of stimulating and training students to correlate and synthesise the data they receive from the different teachings using appropriate tools and methods. As Paul Klee said, "Drawing is the art of taking a line for a walk". In the age of the Digital Twin, are we ready to tackle this path?

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